

10 637 716  
12.05.03

(19)



Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11)

**EP 0 827 265 B1**

(12)

**EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention  
of the grant of the patent:  
**10.04.2002 Bulletin 2002/15**

(21) Application number: **96913733.0**

(22) Date of filing: **13.05.1996**

(51) Int Cl.7: **H02P 5/00**

(86) International application number:  
**PCT/JP96/01253**

(87) International publication number:  
**WO 96/37039 (21.11.1996 Gazette 1996/51)**

(54) **APPARATUS FOR DETERMINATION OF CONTROL CONSTANT**

**VORRICHTUNG ZUR BESTIMMUNG VON REGELUNGSKONSTANTEN**

**APPAREIL DE DETERMINATION DE CONSTANTES DE COMMANDE**

(84) Designated Contracting States:  
**DE GB**

(30) Priority: **17.05.1995 JP 14386995**  
**20.12.1995 JP 34958695**  
**19.04.1996 JP 9850996**

(43) Date of publication of application:  
**04.03.1998 Bulletin 1998/10**

(73) Proprietor: **KABUSHIKI KAISHA YASKAWA**  
**DENKI**  
**Kitakyushu-Shi Fukuoka 806 (JP)**

(72) Inventors:  
• **TSURUTA, Kazuhiko**  
**Kabushiki Kaisha Yaskawa Denki**  
**Kitakyushu-shi Fukuoka 806 (JP)**

• **NAKAMURA, Hiroshi**  
**Kabushiki Kaisha Yaskawa Denki**  
**Kitakyushu-shi Fukuoka 806 (JP)**

(74) Representative: **Grünecker, Kinkeldey,**  
**Stockmair & Schwanhäusser Anwaltssozietät**  
**Maximilianstrasse 58**  
**80538 München (DE)**

(56) References cited:  
**EP-A- 0 604 666** **WO-A-94/14234**  
**JP-A- 2 101 981** **JP-A- 4 325 886**  
**JP-A- 5 346 359** **JP-A- 6 070 566**  
**JP-A- 6 195 128** **JP-A- 6 225 564**  
**JP-A- 6 225 565** **JP-A- 8 015 058**  
**JP-A- 61 088 780**

**EP 0 827 265 B1**

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

## Description

[0001] This invention relates to a control constant identification system of a motor for driving a machine tool for indentifying control constants, such as inertia and viscous friction coefficients.

[0002] From document WO 9414234 there is already known a method and an apparatus for determining constants of functions expressing the characteristics of a controlled system, such as the inertia, and the coefficient of viscous friction of a mechanical device in which an electric motor is incorporated.

[0003] Document EP 0 604 666 discloses a motor control method for driving a control object such as a machine tool, and more specifically a robust adaptive Pi control method which executes adaption of parameters such as inertia, coefficient of dynamic friction etc.

[0004] For example, control constant identification systems include:

(1) an identification system which changes a torque command for changing the rotation speed and calculates torque command integration amount and rotation speed change width, then performs an operation of  $(\text{inertia}) = (\text{torque command integration amount}) / (\text{rotation speed change width})$  for finding inertia (see Japanese Patent Unexamined Publication No. Sho 61-88780);

(2) an identification system which inputs a speed command having a ramp section, executes a speed loop under P control, and finds load inertia from the ratio between steady speed deviation in a state in which no load inertia exists and that in a state in which load inertia exists (see Japanese Patent Unexamined Publication No. Hei 6-70566); and

(3) an identification system which time-integrates actual and simulated current detection values or current command values for finding a current area and corrects an initial inertia assumption value from the current area calculation result, thereby finding inertia (see Japanese Patent Unexamined Publication No. Hei 4-325886).

[0005] However, conventional examples (1), (2), and (3) have a problem that inertia identification value errors or variations are large if viscous friction or Coulomb's friction exists. The following problems are also involved: Particularly in (1), commands are limited to those for changing the rotation speed at a given rate; in (2), the effect of disturbance is easily received because integration control is not performed; and in (3), inertia is found while fuzzy inference, etc., is used to repeat a correction so that the initial inertia assumption value approaches the actual inertia, thus resulting in large amounts of complicated operations.

[0006] It is an object of the invention to provide a control constant identification system that can solve the problem.

[0007] This object is met by the features of claim 1.

[0008] According to the invention, the control constant control system can be provided which contains small inertia identification value errors and variations and moreover can find inertia by performing a small amount of very easy operations even if viscous friction, constant disturbance, and Coulomb's friction exist.

Figure 1 is a principle diagram to explain the basic concept of the invention;

Figure 2 is a block diagram to elaborate on the principle of the invention;

Figure 3 is a block diagram to elaborate on the principle of the invention;

Figure 4 is a block diagram of an embodiment of the invention;

Figure 5 is speed command examples;

Figure 6 is a block diagram to show the speed control section, the estimation section, and the identification section in Figure 4 in detail; and

Figure 7 is an operation example using an AC servo motor.

[0009] First, the principle of the invention will be discussed, next an embodiment using a motor will be described specifically. Figure 1 is a principle diagram to explain the basic concept of the invention. Numeral 1 is a speed control section and numeral 2 is an estimation section. PI control is programmed in the speed control section 1 and only inertia J is to be controlled. Likewise, PI control is also programmed in the estimation section 2 and only inertia J' is to be controlled. In Figure 1, if speed Vfb in the speed control section 1 matches speed Vfb' in the estimation section and Vfb and Vfb' are not zero, relation  $J/J' = STref/STref' \dots (1)$  holds for torque command integration value STref and inertia J in the speed control section and torque command integration value STref' and inertia J' in the estimation section, and inertia J is immediately found from  $J = (STref/STref') \cdot J' \dots (2)$ . This is the basic principle of the invention.

[0010] However, in a system in which viscous friction D exists, the viscous friction D cannot be ignored and to make the relation hold, a condition that the integration value of speed Vfb at a predetermined interval [a, b] is zero must be added. The reason why the condition must be added is as follows: Figure 2 is a block diagram where the targets to be controlled are represented as inertia J and viscous friction D. Figure 3 is a block diagram provided by rewriting Figure 2. As seen in Figure 3, if the integration value of speed Vfb at the interval [a, b] is zero, the effect of the viscous friction D can be eliminated. Thus, if the condition is added, expression (1) holds and the inertia J can be found immediately from expression (2). Here, the integration value of speed Vfb is zero, but if positions are managed, the effect of the viscous friction D may be eliminated if the positions at time a and time b at the interval [a, b] match. An average value of inertia found at a plurality of such intervals at

which the time integration value of motor speed  $V_{fb}$  becomes zero may be adopted as inertia  $J$ . Next, when constant disturbance  $T_d$  is applied, if an average value of inertia  $J_1$  found by one speed command  $V_{ref1}$  and inertia  $J_2$  found by  $V_{ref2}$  provided by inverting the positive and negative of the speed command  $V_{ref1}$  is adopted as inertia  $J$ , the effect of the constant disturbance  $T_d$  can be eliminated. When Coulomb's friction exists, if the interval  $[a, b]$  and the speed command  $V_{ref}$  are set so that the forward rotation time and the reverse rotation time of a motor become equal to each other at the interval  $[a, b]$ , the effect of the Coulomb's friction can also be eliminated. The constant disturbance  $T_d$  can be found by dividing an average value of torque command integration value  $ST_{ref1}$  found by the speed command  $V_{ref1}$  and torque command integration value  $ST_{ref2}$  found by  $V_{ref2}$  provided by inverting the positive and negative of the speed command  $V_{ref1}$  by integration time  $b-a$ . The viscous friction  $D$  can be found from the inclination (time change) of torque command  $T_{ref}$  when the speed command  $V_{ref}$  is constant acceleration or constant deceleration.

**[0011]** Next, an embodiment using a motor will be described specifically. Figure 4 is a block diagram of an embodiment of the invention. In the figure, numeral 41 is a command generation section for outputting a speed command  $V_{ref}$  to a speed control section 42 and an estimation section 43. Numeral 44 is an identification section for inputting a torque command  $T_{ref}$  of the speed control section 42 and a torque command  $T_{ref}'$  of the estimation section 43 and finding inertia  $J$ , constant disturbance  $D$ , and viscous friction  $D$ .

Next, the sections will be discussed with reference to Figures 5 and 6 based on an experimental configuration. Figure 7 shows an operation example using an AC servo motor. The command generation section 41 generates a speed command  $V_{ref}$ . The speed command  $V_{ref}$  can be any of commands as shown in Figures 5(A)-5(F), for example. Here, speed command  $V_{ref}$  shaped like a trapezoid where the absolute values of the maximum speed and the minimum speed are the same and acceleration and deceleration are the same as shown in Figure 5(A) is adopted. Figure 6 shows the configuration of the speed control section 42, the estimation section 43, and the identification section 44. The speed control section 42 programs a speed loop so that speed  $V_{fb}$  matches the speed command  $V_{ref}$ ; here PI (proportional integration) control is adopted. The speed control section 42 outputs a torque command  $T_{ref}$  to a current controller for driving a motor and the identification section 44. Assume that load 4.16 times that of motor inertia  $J_M$ ,  $J_L (=4.16 \cdot J_M)$ , is attached to the motor and that speed  $V_{fb}$  is output from the motor. Like the speed control section 42, the estimation section 43 adopts PI control, models a control target as  $1/J \cdot S$ , and outputs a torque command  $T_{ref}'$  to the control target  $1/J \cdot S$  and the identification section 44. The identification section 44 receives the torque command  $T_{ref}$  output from the speed control section 42

and the torque command  $T_{ref}'$  output from the identification section 43 and finds inertia  $J$  according to  $J = (ST_{ref}/ST_{ref}') \cdot J'$  from values  $ST_{ref}$  and  $ST_{ref}'$  resulting from time integration of the torque commands between time "a" and time "b" and inertia  $J'$  of the estimation section.

**[0012]** Figure 7 provides an operation example using an AC servo motor.  $V_{ref}$  is a speed command, ① is motor speed  $V_{fb}$  in the speed control section 42, ①' is speed  $V_{fb}'$  in the estimation section, ② is a torque command  $T_{ref}$  in the speed control section 42, and ②' is a torque command  $T_{ref}'$  in the estimation section. When inertia  $J_1$  is found from values  $ST_{ref1}$  and  $ST_{ref1}'$  resulting from time integration of ② and ②' between time  $a_1$  and time  $b_1$  and inertia  $J'$  of the estimation section,  $J_1 = (ST_{ref1}/ST_{ref1}') \cdot J' = 5.49 \cdot J_M$ . Likewise, when inertia  $J_2$  is found from values  $ST_{ref2}$  and  $ST_{ref2}'$  resulting from time integration between time  $a_2$  and time  $b_2$  and inertia  $J'$  of the estimation section,  $J_2 = (ST_{ref2}/ST_{ref2}') \cdot J' = 4.81 \cdot J_M$ . Thus, inertia  $J$  can be identified as  $J = (J_1 + J_2)/2 = 5.15 \cdot J_M$ . This identification value almost matches (motor inertia  $J_M$ ) + (load inertia  $J_L = 4.16 \cdot J_M$ ) =  $5.16 \cdot J_M$ . However, inertia  $J'$  of the estimation section is simulated as  $J' = J_M$ . In the experiment, the operations of the estimation section are also performed in real time. However, if the speed command  $V_{ref}$  is fixed, the torque command integration value  $ST_{ref}'$  in the estimation section can be previously calculated, thus only the torque command integration value  $ST_{ref}$  in the speed control section 42 needs to be calculated.

**[0013]** In fact, if the speed becomes zero, the relation of expression (1) does not hold because of the effect of statical friction. Therefore, when the speed  $V_{fb}$  is  $X_1 \leq V_{fb} \leq X_2$  (where  $X_1 \leq 0$  and  $X_2 \geq 0$ ), if time integration of the torque command  $T_{ref}$  of the speed control section and the torque command  $T_{ref}'$  of the estimation section is not executed,  $J/J' = ST_{ref}/ST_{ref}'$  holds and inertia  $J$  is immediately found from expression  $J = (ST_{ref}/ST_{ref}') \cdot J'$ . When viscous friction  $D$  exists as in Figure 2, as seen in Figure 3 provided by rewriting Figure 2, if the integration value of the speed  $V_{fb}$  at the interval  $[a, b]$  is zero, the effect of the viscous friction  $D$  can be eliminated. Thus, when the speed  $V_{fb}$  is  $X_1 \leq V_{fb} \leq X_2$  (where  $X_1 \leq 0$  and  $X_2 \geq 0$ ), if time integration of the torque command  $T_{ref}$  of the speed control section and the torque command  $T_{ref}'$  of the estimation section is not executed and the interval  $[a, b]$  and the speed command  $V_{ref}$  are set so that the time integration value of the speed  $V_{fb}$  becomes zero except during the time  $t_1$  ( $t_1 \geq 0$ ) when the speed  $V_{fb}$  is  $X_1 \leq V_{fb} \leq X_2$ , the effect of the viscous friction  $D$  can also be eliminated. Thus, a control constant control system can be provided that can identify inertia without receiving the effect of statical friction, etc., occurring when the speed is zero or is close to zero.

**[0014]** If the actual operation and the model operation differ largely, the speed  $V_{fb}$  in the speed control section and the speed  $V_{fb}'$  in the estimation section may be hard

to match. In this case, an adjustment section 45 for adjusting speed loop gain  $K_v'$  may be provided, as shown in Figure 6.

[0015] The adjustment section raises the speed loop gain  $K_v'$  of the estimation section if the torque command  $T_{ref}'$  of the estimation section is greater than 0 and the speed  $V_{fb}$  is greater than the speed  $V_{fb}'$ ;

lowers the speed loop gain  $K_v'$  of the estimation section if the torque command  $T_{ref}'$  of the estimation section is less than 0 and the speed  $V_{fb}$  is greater than the speed  $V_{fb}'$ ; and  
raises the speed loop gain  $K_v'$  of the estimation section if the torque command  $T_{ref}'$  of the estimation section is less than 0 and the speed  $V_{fb}$  is less than the speed  $V_{fb}'$ .

[0016] This invention can be applied to control systems of motors for driving industrial machines, particularly machine tools, sorting machines, etc., with less load change.

#### Claims

1. A control constant identification system of an electrical motor for driving a machine tool for identifying control constants comprising:

a command generation section (41) for generating a speed command  $V_{ref}$ ;

a speed control section (42) for determining a torque command  $T_{ref}$  by the speed command  $V_{ref}$  and actual motor speed  $V_{fb}$  and for controlling motor speed;

an estimation section (43) for determining an estimated torque command  $T_{ref}'$  by the speed command  $V_{ref}$  by simulating said speed control section according to a model; and

an identification section (44) for identifying inertia  $J$  according to a ratio between a value  $St_{ref}$  resulting from time integration of the torque command  $T_{ref}$  output by said speed control section (42) at a predetermined interval  $[a, b]$  and a value  $St_{ref}'$  resulting from time integration of the torque command  $T_{ref}'$  output by said estimation section (43) at the predetermined interval  $[a, b]$ , wherein

the predetermined interval  $[a, b]$  and the speed command  $V_{ref}$  are set so that the actual motor speed  $V_{fb}$  and motor speed  $V_{fb}'$  found by said estimation section become the same non-zero values at the time  $b$ .

2. Control constant identification system as claimed in claim 1, wherein the speed command  $V_{ref}$  generated by said command generation section (41) is previously fixed.

3. Control constant identification system as claimed in claim 1 or 2, wherein said speed control section (42) performs control containing an integration operation.

4. Control constant identification system as claimed in any one of claims 1 to 3, wherein the predetermined interval  $[a, b]$  and the speed command  $V_{ref}$  are set so that a time integration value of the actual motor speed  $V_{fb}$  at the predetermined interval  $[a, b]$  becomes zero.

5. Control constant identification system as claimed in any one of claims 1 to 4, wherein an average value of inertia found at a plurality of such intervals at which the time integration value of the actual motor speed  $V_{fb}$  becomes zero is adopted as inertia  $J$ .

6. Control constant identification system as claimed in any one of claims 1 to 3, wherein the interval  $[a, b]$  and the speed command  $V_{ref}$  are set so that forward rotation time and reverse rotation time of a motor become equal to each other at the interval  $[a, b]$ .

7. Control constant identification system as claimed in any one of claims 1 to 6, wherein an average value of inertia  $J_1$  found by one speed command  $V_{ref1}$  and inertia  $J_2$  found by  $V_{ref2}$  provided by inverting positive and negative of the speed command  $V_{ref1}$  is adopted as inertia  $J$ .

8. Control constant identification system as claimed in claim 7, wherein constant disturbance  $T_d$  is found according to a torque command integration value  $St_{ref1}$  found by one speed command  $V_{ref1}$  and a torque command integration value  $St_{ref2}$  found by  $V_{ref2}$  provided by inverting the positive and negative of the speed command  $V_{ref1}$ .

9. Control constant identification system as claimed in any one of claims 1 to 3, wherein a viscous friction coefficient  $D$  is found from inclination (time change) of the torque command  $T_{ref}$  when the speed command  $V_{ref}$  is constant acceleration or constant deceleration.

10. Control constant identification system as claimed in claim 1, wherein when the actual motor speed  $V_{fb}$  satisfies the following relationship:

$$X_1 \leq V_{fb} \leq X_2 \text{ (where } X_1 \leq 0 \text{ and } X_2 \geq 0 \text{)}$$

in the predetermined interval [a, b], time integration of the torque command  $T_{ref}$  of said speed control section and the torque command  $T_{ref}'$  of said estimation section are not executed.

11. Control constant identification system as claimed in claim 1, wherein the predetermined speed command  $V_{ref}$  are set such that a time integration value of the actual motor speed  $V_{fb}$  becomes zero except during a time  $t_1$  ( $t_1 \geq 0$ ) when the actual motor speed  $V_{fb}$  satisfies the following relationship:

$$X1 \leq V_{fb} \leq X2.$$

12. Control constant identification system as claimed in claim 1, further including an adjustment section (45) for adjusting speed loop gain  $K_v'$  of said estimation section (43) from information of the motor speed  $V_{fb}$  of said speed control section, and the speed  $V_{fb}'$  and the torque command  $T_{ref}$  of said estimation section (43).

13. Control constant identification system as claimed in claim 12, wherein said adjustment section (45) raises the speed loop gain  $K_v'$  of said estimation section (43) if the torque command  $T_{ref}'$  of said estimation section is greater than 0 and the actual motor speed  $V_{fb}$  is greater than the motor speed  $V_{fb}'$ ;

lowers the speed loop gain  $K_v'$  of said estimation section (43) if the torque command  $T_{ref}'$  of said estimation section (43) is less than 0 and the actual motor speed  $V_{fb}$  is greater than the motor speed  $V_{fb}'$ ; and

raises the speed loop gain  $K_v'$  of said estimation section if the torque command  $T_{ref}'$  of said estimation section (43) is less than 0 and the actual motor speed  $V_{fb}$  is less than the motor speed  $V_{fb}'$ .

#### Patentansprüche

1. Regelungskonstanten-Bestimmungssystem eines elektrischen Motors für den Antrieb einer Werkzeugmaschine zum Bestimmen von Regelungskonstanten, welches umfaßt:

einen Führungsgrößen-Erzeugungsabschnitt (41) zum Erzeugen einer Drehzahlführungsgröße  $V_{ref}$ ;

einen Drehzahlregelungsabschnitt (42) zum Bestimmen einer Drehmomentführungsgröße  $T_{ref}$  mittels der Drehzahlführungsgröße  $V_{ref}$  und der tatsächlichen Motorgeschwindigkeit  $V_{fb}$ , und zum Regeln einer Motordrehzahl;

einen Abschätzungsabschnitt (43) zum Bestimmen einer abgeschätzten Drehmomentführungsgröße  $T_{ref}'$  durch die Drehzahlführungsgröße  $V_{ref}$ , indem der Drehzahlregelungsabschnitt gemäß einem Modell simuliert wird; und

einen Bestimmungsabschnitt (44) zum Bestimmen der Trägheit  $J$  anhand eines Verhältnisses zwischen einem Wert  $ST_{ref}$ , welches sich aus einer zeitlichen Integration der von dem Drehzahlregelungsabschnitt (42) ausgegebenen Führungsgröße  $T_{ref}$  bei einem vorbestimmten Intervall [a, b] und einem Wert  $ST_{ref}'$ , resultierend aus der zeitlichen Integration der von dem Abstimmungsabschnitt (43) ausgegebene Drehmomentführungsgröße  $T_{ref}'$  bei dem vorbestimmten Intervall [a, b] ergibt, wobei

das vorbestimmte Intervall [a, b] und die Drehzahlführungsgröße  $V_{ref}$  so eingestellt werden, daß die tatsächliche Motordrehzahl  $V_{fb}$  und die Motordrehzahl  $V_{fb}'$  die von dem Abschätzungsabschnitt gefunden werden, dieselben Nicht-Nullwerte zu dem Zeitpunkt b werden.

2. Regelungskonstanten-Bestimmungssystem nach Anspruch 1, wobei die von dem Führungsgrößen-Erzeugungsabschnitt (41) erzeugte Drehzahlführungsgröße  $V_{ref}$  im voraus festgelegt ist.

3. Regelungskonstanten-Bestimmungssystem nach Anspruch 1 oder 2, wobei der Drehzahlregelungsabschnitt (42) eine eine Integrationsoperation enthaltende Regelung durchführt.

4. Regelungskonstanten-Bestimmungssystem nach einem der Ansprüche 1 bis 3, wobei das vorbestimmte Intervall [a, b] und die Drehzahlführungsgröße  $V_{ref}$  so eingestellt werden, daß ein zeitlicher Integrationswert der tatsächlichen Motordrehzahl  $V_{fb}$  bei dem vorbestimmten Intervall [a, b] zu Null wird.

5. Regelungskonstanten-Bestimmungssystem nach einem der Ansprüche 1 bis 4, wobei ein bei einer Vielzahl derartiger Intervalle gefundener Mittelwert der Trägheit, bei welchen der zeitliche Integrationswert der tatsächlichen Motordrehzahl  $V_{fb}$  zu Null wird, als Trägheit  $J$  genommen wird.

6. Regelungskonstanten-Bestimmungssystem nach einem der Ansprüche 1 bis 3, wobei das Intervall [a, b] und die Drehzahlführungsgröße  $V_{ref}$  so eingestellt werden, daß die Vorwärtsrotationszeit und die Rückwärtsrotationszeit eines Motors bei dem Intervall [a, b] zueinander gleich werden.

7. Regelungskonstanten-Bestimmungssystem nach einem der Ansprüche 1 bis 6, wobei ein Mittelwert einer durch eine Drehzahlführungsgröße  $V_{ref1}$  gefundenen Trägheit  $J_1$  und einer durch eine  $V_{ref2}$ , erzeugt durch Invertieren positiver und negativer Anteile der Drehzahlführungsgröße  $V_{ref1}$ , gefundenen Trägheit  $J_2$  als Trägheit  $J$  genommen wird. 5
8. Regelungskonstanten-Identifizierungssystem nach Anspruch 7, wobei eine konstante Regelungsabweichung  $T_d$  anhand eines Drehmomentführungsgrößen-Integrationswertes  $ST_{ref1}$  gefunden durch eine Drehzahlführungsgröße  $V_{ref1}$  und eines Drehmomentführungsgrößen-Integrationswertes  $ST_{ref2}$ , gefunden durch  $V_{ref2}$ , erzeugt durch Invertieren der positiven und negativen Anteile der Drehzahlführungsgröße  $V_{ref1}$ , gefunden wird. 10 15
9. Regelungskonstanten-Bestimmungssystem nach einem der Ansprüche 1 bis 3, wobei ein Koeffizient  $D$  einer viskosen Reibung aus der Steigung (zeitlichen Veränderung) der Drehmomentführungsgröße  $T_{ref}$  gefunden wird, wenn die Drehzahlführungsgröße  $V_{ref}$  eine konstante Beschleunigung oder konstante Abbremsung ist. 20 25

10. Regelungskonstanten-Bestimmungssystem nach Anspruch 1, wobei, wenn die tatsächliche Motordrehzahl  $V_{fb}$  der folgende Beziehung: 30

$$X_1 \leq V_{fb} \leq X_2 \text{ (wobei } X_1 \leq 0 \text{ und } X_2 \geq 0 \text{)}$$

in dem vorbestimmten Intervall  $[a, b]$  genügt, die zeitliche Integration der Drehmomentführungsgröße  $T_{ref}$  des Drehzahlregelungsabschnittes und der Drehmomentführungsgröße  $T_{ref}'$  des Abschätzungsabschnittes nicht ausgeführt werden. 35

11. Regelungskonstanten-Bestimmungssystem nach Anspruch 1, wobei die vorbestimmte Drehzahlführungsgröße  $V_{ref}$  so eingestellt wird, daß ein zeitlicher Integrationswert der tatsächlichen Motordrehzahl  $V_{fb}$  zu Null wird, außer während einer Zeit  $t_1$  ( $t_1 \geq 0$ ), wenn die tatsächliche Motordrehzahl  $V_{fb}$  der nachstehenden Beziehung genügt: 40 45

$$X_1 \leq V_{fb} \leq X_2.$$

12. Regelungskonstanten-Bestimmungssystem nach Anspruch 1, ferner mit einem Anpassungsabschnitt (45) zum Anpassen der Drehzahlschleifenverstärkung  $K_v'$  des Abschätzungsabschnittes (43) aus einer Information der Motordrehzahl  $V_{fb}$  des Drehzahlregelungsabschnittes und der Drehzahl  $V_{fb}'$  und der Drehmomentführungsgröße  $T_{ref}'$  des Abschätzungsabschnittes (43). 50 55

13. Regelungskonstanten-Bestimmungssystem nach Anspruch 12, wobei:

der Anpassungsabschnitt (45) die Drehzahlschleifenverstärkung  $K_v'$  des Abschätzungsabschnittes (43) anhebt, wenn die Drehmomentführungsgröße  $T_{ref}'$  des Abschätzungsabschnittes größer als 0 ist, und die tatsächliche Motordrehzahl  $V_{fb}$  größer als die Motordrehzahl  $V_{fb}'$  ist; die Drehzahlschleifenverstärkung  $K_v'$  des Abschätzungsabschnittes verringert, wenn die Drehmomentführungsgröße  $T_{ref}'$  des Abschätzungsabschnittes (43) kleiner als 0 und die tatsächliche Motordrehzahl  $V_{fb}$  größer als die Motordrehzahl  $V_{fb}'$  ist; und die Drehzahlschleifenverstärkung  $K_v'$  des Abschätzungsabschnittes anhebt, wenn die Drehmomentführungsgröße  $T_{ref}'$  des Abschätzungsabschnittes (43) kleiner als 0 und die tatsächliche Motordrehzahl  $V_{fb}$  kleiner als die Motordrehzahl  $V_{fb}'$  ist.

## Revendications

1. Système d'identification de constante de commande d'un moteur électrique pour entraîner une machine-outil pour identifier des constantes de commande, comprenant :

une section de génération de commande (41) pour générer une commande de vitesse  $V_{ref}$  ; une section de commande de vitesse (42) pour déterminer une commande de couple  $T_{ref}$  au moyen de la commande de vitesse  $V_{ref}$  et d'une vitesse de moteur réelle  $V_{fb}$  et pour commander une vitesse de moteur ; une section d'estimation (43) pour déterminer une commande de couple estimée  $T_{ref}'$  au moyen de la commande de vitesse  $V_{ref}$  en simulant ladite section de commande de vitesse conformément à un modèle ; et une section d'identification (44) pour identifier une inertie  $J$  conformément à un rapport entre une valeur  $ST_{ref}$  résultant d'une intégration sur le temps de la commande de couple  $T_{ref}$  qui est émise en sortie par ladite section de commande de vitesse (42) pour un intervalle prédéterminé  $[a, b]$  et une valeur  $ST_{ref}'$  résultant d'une intégration sur le temps de la commande de couple  $T_{ref}'$  qui est émise en sortie par ladite section d'estimation (43) pour l'intervalle prédéterminé  $[a, b]$ , 50

dans lequel :

l'intervalle prédéterminé  $[a, b]$  et la commande

de vitesse  $V_{ref}$  sont établis de telle sorte que la vitesse de moteur réelle  $V_{fb}$  et la vitesse de moteur  $V_{fb}'$  comme trouvé par ladite section d'estimation deviennent les mêmes valeurs non nulles à l'instant b.

2. Système d'identification de constante de commande selon la revendication 1, dans lequel la commande de vitesse  $V_{ref}$  qui est générée par ladite section de génération de commande (41) est fixée au préalable.
3. Système d'identification de constante de commande selon la revendication 1 ou 2, dans lequel ladite section de commande de vitesse (42) réalise une commande qui contient une opération d'intégration.
4. Système d'identification de constante de commande selon l'une quelconque des revendications 1 à 3, dans lequel l'intervalle prédéterminé  $[a, b]$  et la commande de vitesse  $V_{ref}$  sont établis de telle sorte qu'une valeur d'intégration sur le temps de la vitesse de moteur réelle  $V_{fb}$  pour l'intervalle prédéterminé  $[a, b]$  devienne égale à zéro.
5. Système d'identification de constante de commande selon l'une quelconque des revendications 1 à 4, dans lequel une valeur moyenne d'inertie trouvée pour une pluralité des intervalles pour lesquels la valeur d'intégration sur le temps de la vitesse de moteur réelle  $V_{fb}$  devient égale à zéro est adoptée en tant qu'inertie J.
6. Système d'identification de constante de commande selon l'une quelconque des revendications 1 à 3, dans lequel l'intervalle  $[a, b]$  et la commande de vitesse  $V_{ref}$  sont établis de telle sorte qu'un temps de rotation en sens direct et qu'un temps de rotation en sens inverse d'un moteur deviennent égaux l'un à l'autre pour l'intervalle  $[a, b]$ .
7. Système d'identification de constante de commande selon l'une quelconque des revendications 1 à 6, dans lequel une valeur moyenne entre une inertie  $J_1$  trouvée au moyen d'une commande de vitesse  $V_{ref1}$  et une inertie  $J_2$  trouvée au moyen de  $V_{ref2}$  comme produit en inversant le positif et le négatif de la commande de vitesse  $V_{ref1}$  est adoptée en tant qu'inertie J.
8. Système d'identification de constante de commande selon la revendication 7, dans lequel une perturbation constante  $T_d$  est trouvée conformément à une valeur d'intégration de commande de couple  $Stref1$  trouvée au moyen d'une commande de vitesse  $V_{ref1}$  et conformément à une valeur d'intégration de commande de couple  $Stref2$  trouvée au moyen d'une commande de vitesse  $V_{ref2}$  comme produit

en inversant le positif et le négatif de la commande de vitesse  $V_{ref1}$ .

9. Système d'identification de constante de commande selon l'une quelconque des revendications 1 à 3, dans lequel un coefficient de friction visqueuse D est trouvé à partir d'une inclinaison (variation temporelle) de la commande de couple  $T_{ref}$  lorsque la commande de vitesse  $V_{ref}$  est une accélération constante ou une décélération constante.
10. Système d'identification de constante de commande selon la revendication 1, dans lequel, lorsque la vitesse de moteur réelle  $V_{fb}$  satisfait la relation qui suit :

$$X1 \leq V_{fb} \leq X2 \text{ (où } X1 \leq 0 \text{ et } X2 \geq 0 \text{)}$$

dans l'intervalle prédéterminé  $[a, b]$ , une intégration sur le temps de la commande de couple  $T_{ref}$  de ladite section de commande de vitesse et de la commande de couple  $T_{ref}'$  de ladite section d'estimation ne sont pas exécutées.

11. Système d'identification de constante de commande selon la revendication 1, dans lequel la commande de vitesse prédéterminée  $V_{ref}$  est établie de telle sorte qu'une valeur d'intégration sur le temps de la vitesse de moteur réelle  $V_{fb}$  devienne égale à zéro à l'exception de pendant un temps  $t_1$  ( $t_1 \geq 0$ ) lorsque la vitesse de moteur réelle  $V_{fb}$  satisfait la relation qui suit :

$$X1 \leq V_{fb} \leq X2.$$

12. Système d'identification de constante de commande selon la revendication 1, incluant en outre une section de réglage (45) pour régler un gain de boucle de vitesse  $K_v'$  de ladite section d'estimation (43) à partir d'une information de la vitesse de moteur  $V_{fb}$  de ladite section de commande de vitesse, et de la vitesse  $V_{fb}'$  et de la commande de couple  $T_{ref}'$  de ladite section d'estimation (43).
13. Système d'identification de constante de commande selon la revendication 12, dans lequel ladite section de réglage (45) augmente le gain de boucle de vitesse  $K_v'$  de ladite section d'estimation (43) si la commande de couple  $T_{ref}'$  de ladite section d'estimation est supérieure à zéro et si la vitesse de moteur réelle  $V_{fb}$  est supérieure à la vitesse de moteur  $V_{fb}'$ , elle abaisse le gain de boucle de vitesse  $K_v'$  de ladite section d'estimation (43) si la commande de couple  $T_{ref}'$  de ladite section d'estimation (43) est inférieure à zéro et si la vitesse de moteur réelle  $V_{fb}$  est supérieure à la vitesse de moteur  $V_{fb}'$ ; et

elle augmente le gain de boucle de vitesse  $K_v'$  de ladite section d'estimation si la commande de couple  $T_{ref}'$  de ladite section d'estimation (43) est inférieure à zéro et si la vitesse de moteur réelle  $V_{fb}$  est inférieure à la vitesse de moteur  $V_{fb}'$ .

5

10

15

20

25

30

35

40

45

50

55



FIG. 1

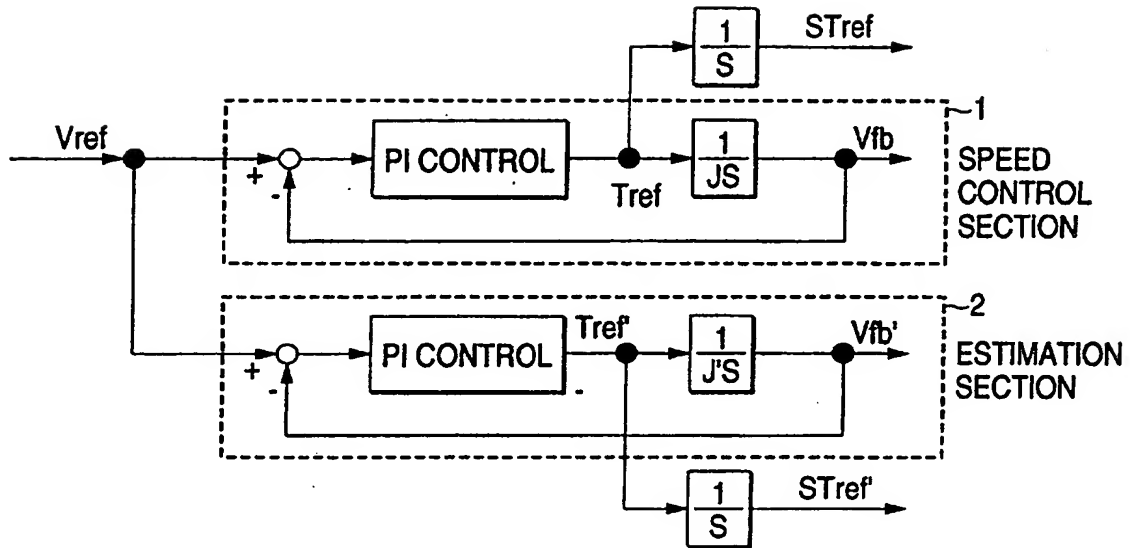


FIG. 2

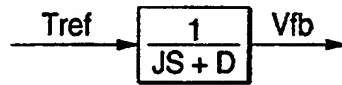


FIG. 3

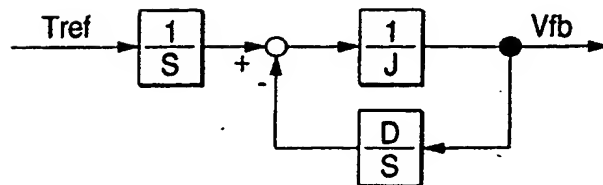


FIG. 4

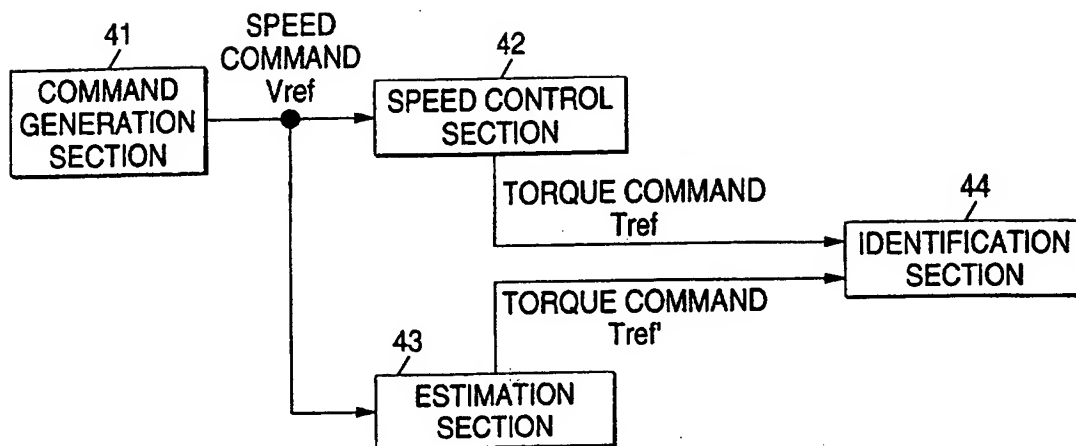


FIG. 5

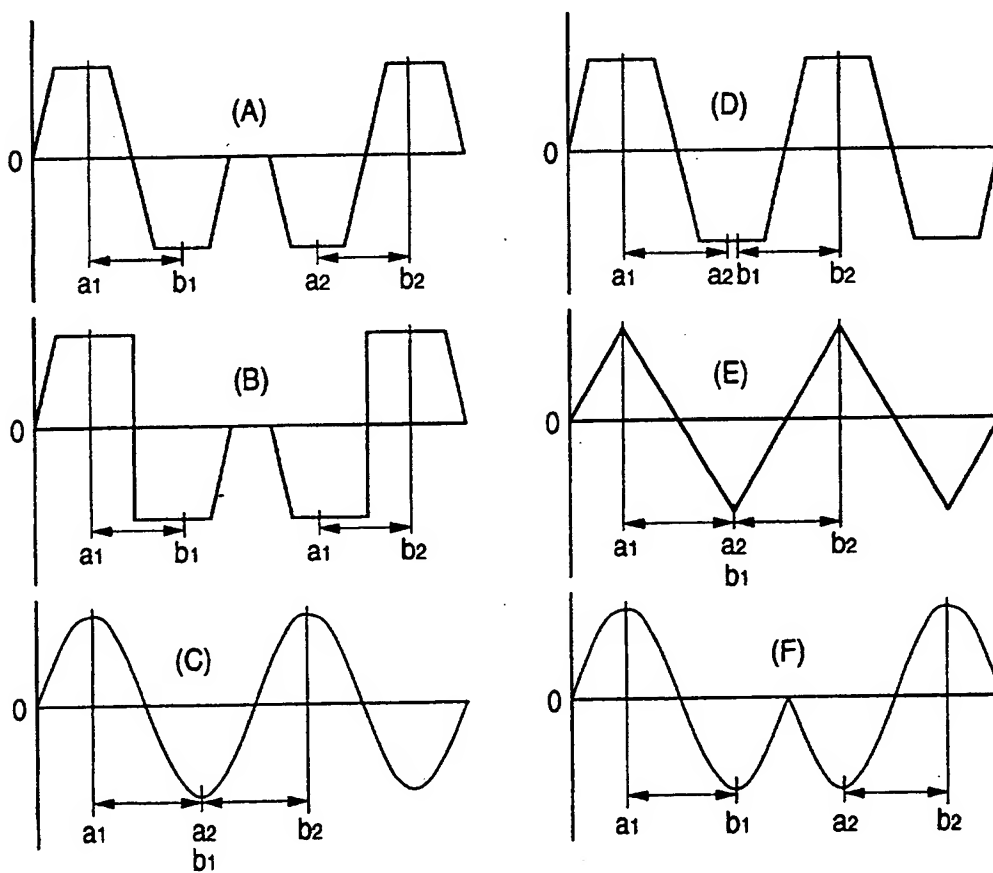


FIG. 6

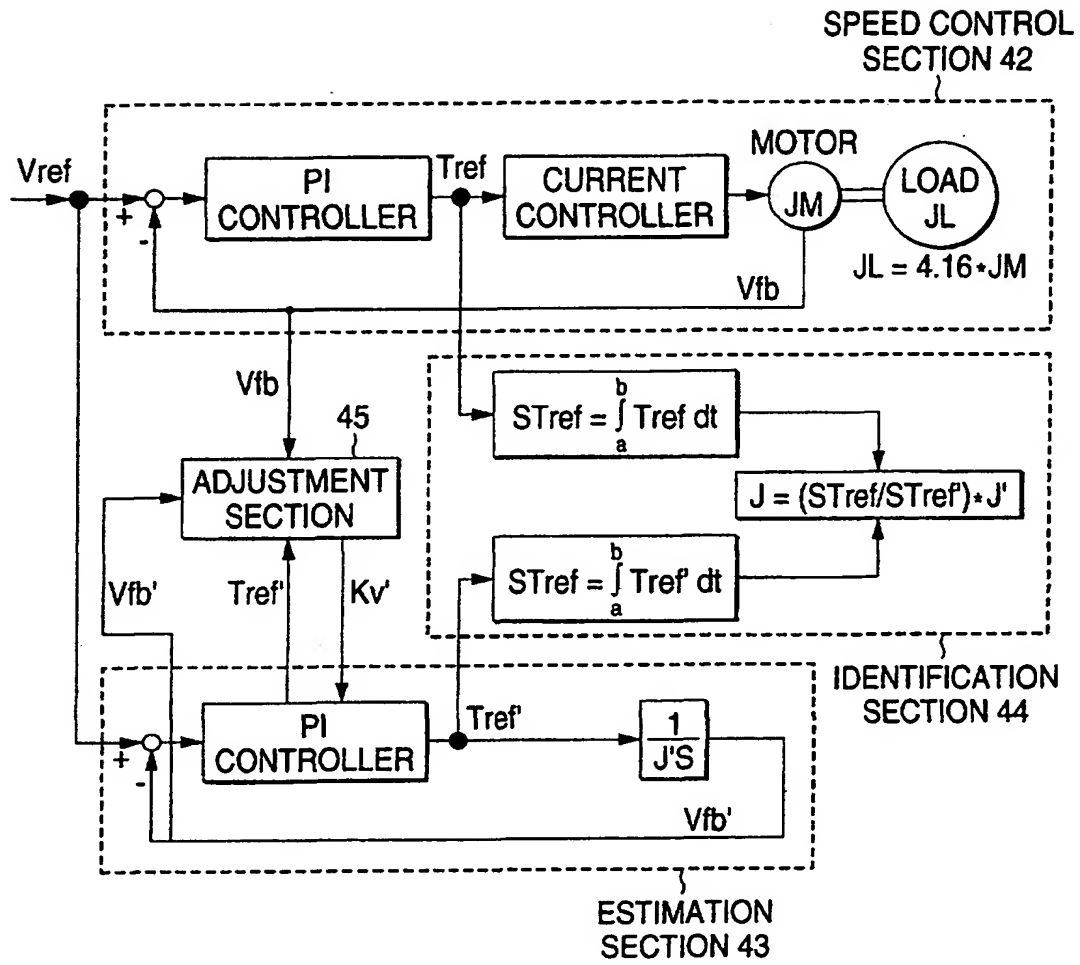


FIG. 7

